HEAT EXCHANGE APPARATUS, SYSTEM, AND METHODS REGARDING SAME

Cross Reference to Related Applications

This application claims the benefit of U.S. Provisional Application No. 60/429,160, entitled "A Geothermal Loopless Exchanger," filed 27 November 2002, wherein such document is incorporated herein by reference.

Background of the Invention

The present invention relates generally to heating and cooling apparatus, methods, and systems. More particularly, the present invention pertains to the use of heat exchangers in such heating and cooling apparatus, methods, and systems.

Various geothermal heating and cooling systems for providing space conditioning, including heating, cooling, and humidity control, are available. Such geothermal systems may also provide water heating, either to supplement or replace conventional water heaters, pool heating and cooling, and refrigeration.

Many exemplary heat reclamation systems and earth exchange systems (e.g., systems that are gravity flow, expensive, complicated, and require periodic cleaning and maintenance to avoid fouling (e.g., contamination of water supplies) and/or degradation of heat recovery efficiency) have been described. For example, various systems are shown in U.S. Patent No. 4,321,798, entitled "Method for Heating Water Used in an Appliance Connected Into a Domestic Water Circuit and the Apparatus for Carrying Out said Method," to Palazzetti et al., issued 30 March 1982; U.S. Patent No. 4,352,391, entitled "Method and Apparatus for Recovering Heat in Waste Water," to Jonsson, issued 5 October 1982; U.S. Patent No. 4,150,787, entitled "Method and Arrangement for Saving Energy in Preparing Hot Water for Household," to Braathen, issued 24 April 1979; U.S. Patent No. 4,300,247, entitled "Energy Conservation in Shower Bathing," to Berg, issued 17 November 1981; U.S. Patent No. 4,304,292,

entitled "Shower," to Cardone et al., issued 8 December 1981; U.S. Patent No. 4,372,372, entitled "Shower Bath Economizer," to Hunter, issued 8 February 1983; U.S. Patent No. 6,041,613, entitled "Energy Conserving Heat Pump System," to Morse et al., issued 28 March 2000; U.S. Patent No. 4,619,311, entitled "Equal Volume, Contraflow Heat Exchanger," to Vasile et al., issued 28 October 1986; U.S. Patent No. 4,538,418, entitled "Heat Pump," to Lawrence et al., issued 3 September 1985; U.S. Patent No. 6,138,744, entitled "Closed Loop Geothermal Heat Exchanger," to Coffee, issued 31 October 2000; U.S. Patent No. 5,671,608, entitled "Geothermal Direct Expansion Heat Pump System," to Wiggs et al., issued 30 September 1997; and U.S. Patent No. 4,782,888, entitled "Community Thermal Energy Exchange System," to Bardenheier, issued 8 November 1988.

A geothermal exchange system, at least in one embodiment, can generally be described as a system that simply transfers thermal energy (e.g., heat) from the ground or groundwater into a space (e.g., a space being conditioned during the winter months) and/or transfers thermal energy (e.g., heat) from the space (e.g., a space being conditioned in the summer months) back into the ground or groundwater. As the temperature of the ground or groundwater remains fairly constant throughout the year, ranging from, for example, about 35° to 65° Fahrenheit in northern latitudes, operating efficiencies are high year-round.

For example, in many instances, a geothermal exchange system may include a distribution system (e.g., a fan and/or duct work or a water distribution system) that distributes thermal energy within a space or object being heated or cooled; a ground or groundwater heat exchanger that absorbs thermal energy (e.g., heat) from the earth or water, or discharges thermal energy (e.g., heat) to the earth or water; and a heat pump apparatus that transfers thermal energy between the distribution system and the ground or groundwater heat exchanger.

Generally, the distribution system is typical of any heating or cooling system (e.g., a conventional furnace). For example, a fan moves heated or cooled air through ducts to individual spaces and returns air therethrough to the geothermal exchange system.

The geothermal heat pump apparatus may be a water source geothermal heat pump or a direct exchange (DX) heat pump. Water source geothermal heat pumps extract energy from the ground or ground water sources. The water source geothermal heat pumps can either be used in an open loop geothermal system or a closed loop geothermal system.

In the case of an open loop system, water from a water well, lake, river, pond or running spring (i.e., a water source) is piped to the heat pump apparatus. The water goes through a small heat exchanger inside the heat pump apparatus located next to a refrigerant compressor also inside the heat pump. The small heat exchanger of the heat pump includes coil pipes containing the refrigerant (e.g., freon) that are wrapped with a coil containing the ground water piped to the heat pump apparatus. The ground water piped to the heat pump apparatus (e.g., typically around 50 to 60 degrees Fahrenheit) is used to modify the temperature of the refrigerant in coils of the small heat exchanger of the heat pump. After the water is pumped from the water source through the small water-to-refrigerant heat exchanger of the heat pump, the water is returned to the same or a different water source.

As an alternative to running the pumped ground water in the open loop system directly to the coil of the small heat exchanger that also includes the coils containing refrigerant, the heat pump may include an additional heat exchanger (e.g., such as, a plate and frame or a shell and tube heat exchanger) that can be used to receive the ground water piped to the heat pump. The additional heat exchanger receives the pumped ground water on one side thereof and includes a closed loop pipe on the other side that is associated with a portion of the small heat exchanger that includes refrigerant in one set of coils thereof. The closed loop pipe may contain, for example, water and an anti-freeze type solution (e.g., a solution containing a glycol component). The closed loop pipe containing water and anti-freeze solution extracts energy from the ground water piped to the additional heat exchanger. This open loop system including use of the additional heat exchanger is usually used where the ground water is of poor quality and/or contains minerals that cause corrosion, etc. The additional heat exchanger through which the ground water is piped is less expensive to replace than the small heat exchanger containing the refrigerant.

Closed loop systems are generally of two types, horizontal and vertical. In a horizontal closed loop system, a series of horizontal pipes (e.g., high density polyethylene (HDPE) pipes) is placed in the ground and connected to the heat pump apparatus such that a solution flowing through the closed loop flows through a small heat exchanger inside the heat pump apparatus located next to the refrigerant compressor, which is also inside the heat pump. The closed loop contains a solution (e.g., usually a water and anti-freeze solution (e.g., a solution containing a glycol component). As the solution flows through the closed loop, and as such, through the buried pipes in the ground, the solution extracts the thermal energy from the ground and transfers it to the small heat exchanger in the heat pump. Like the open loop system, the small heat exchanger of the heat pump includes coil pipes containing the refrigerant (e.g., freon) that are wrapped with a coil containing the solution that is flowing in the closed loop. The solution flowing in the closed loop that has been modified by the ground is used to modify the temperature of the refrigerant in the coils of the small heat exchanger of the heat pump apparatus.

A vertical closed loop system operates in substantially the same manner as the horizontal pipe closed loop system with one exception. In the vertical closed loop system, the pipes are placed vertically in bored holes in the ground.

Generally, in such water source heat pump closed systems, in both the vertical and the horizontal closed loops, water or a water/antifreeze mixture in the pipes remains within the pipes for the life of the system.

With respect to both the open loop and closed loop systems, the geothermal heat pump apparatus may be configured as a water to air, water source geothermal heat pump or a water to water, water source geothermal heat pump. In the water to air, water source geothermal heat pump configuration, the heat pump is associated with a forced air system that distributes hot or cold air through a conventional duct system for both supply and return air. In the water to water, water source geothermal heat pump, the heat pump is associated with a distribution system that distributes heating and cooling through infloor radiant tubes or air handlers with water coils. A water to water, water source geothermal heat pump has the capability of heating water to 130 degrees Fahrenheit or cooling to 14 degrees Fahrenheit.

Generally, a geothermal water to air, water source heat pump operates similarly to a conventional forced air furnace in terms of hot and cold air distribution for the system in which it is used. For example, air ducts and an air mover are used to distribute hot or cold air throughout a space. However, with a conventional furnace and air conditioner, the starting point is always the outside temperature, whether it be 10° below 0 or 90° above 0. This is also the case for air to air heat pumps. Such units do not function effectively in temperatures below 30°. Contrary to such systems, with a geothermal water source heat pump, the starting point for such a thermal energy exchange system is the ground or groundwater temperature.

With respect to the use of a DX heat pump in a geothermal heat exchange system, a DX heat pump system, unlike a water source heat pump system, uses a refrigerant closed loop including lines thereof placed either horizontally or vertically in the ground. Instead of HDPE pipe, generally, copper pipe is used. As the refrigerant flows through the copper ground pipes, the refrigerant extracts thermal energy from the earth and transfers it directly into the compressor of the heat pump. The problems associated with DX heat pump systems is the short life of the buried copper pipe, unless a sacrificial metal softer than the copper is buried with the copper tubing.

In operation, for example, of a DX heat pump closed system, a heating cycle begins with the refrigerant flowing through the buried loops where it absorbs thermal energy (e.g., heat) from the ground or groundwater and evaporates to form a cooled gas (i.e., acting as an evaporator). The ground or groundwater in which the loops are buried give up heat as the refrigerant flows through the buried loops. The gaseous refrigerant from the evaporator passes through conduit to a compressor, which compresses it, and raises its temperature and pressure.

The hot, compressed gas then flows to an air handler associated with an air distribution system (e.g., when an air distribution system is used) which acts as a condenser in the heating mode. Here, air flowing across the condenser absorbs heat from the refrigerant and carries it throughout the space being heated. As the refrigerant releases its heat, the refrigerant condenses to form a liquid, which then flows through an expansion device that reduces its pressure

and, consequently, lowers its temperature again. Finally, the refrigerant reenters the evaporator (e.g., including the buried piping loops), and the cycle is repeated.

For cooling, the above process is reversed. The compressor sends the hot, dense gas directly to the buried piping loops (i.e., now acting as the condenser). The ground or groundwater absorbs thermal energy (e.g., heat) from the refrigerant in the buried loops. As the refrigerant gives up heat to the ground or groundwater, the refrigerant cools and condenses into a liquid. The cool liquid refrigerant flows through an expansion device (e.g., using an orifice or a valve), which further lowers its temperature and pressure. The cold liquid refrigerant then flows through an air handler associated with the air distribution system (e.g., when an air distribution system is used) (i.e., which now acts as the evaporator). For example, air from the space flows across the evaporator tubing, giving up heat to the refrigerant inside the tubes. The cooler air is moved through the space via, for example, duct work. The warmed refrigerant evaporates as it absorbs heat from the air, and then returns to the compressor to repeat the cycle.

As described above, many previously installed geothermal systems are associated with a closed ground loop (e.g., closed ground loop systems that comprise buried pipes circulating through the ground which extract energy from the ground as fluid therein circulates). In northern climates, the ground loops can get as cold as, for example, 28° in the winter and as warm as 72° in the summer. Such systems, in many cases, function effectively, however, they are generally expensive to install.

Although various geothermal systems are available, such systems have associated disadvantages. For example, the cost of installation for closed or open loop systems is generally high, as well as are operational costs. Further, for example, many of such systems are somewhat complex. Likewise, open loop groundwater systems are difficult to get permitted by regulatory authorities and further, many closed loop systems work inefficiently, and sometimes not at all, in warmer climates.

Summary of the Invention

The present invention, as described below, addresses various problems described above and other problems of prior art systems or methods which will become apparent to one skilled in the art from the description below. Generally, the present invention provides a thermal energy exchange system for use with an existing conduit that is in a flooded state. The system includes a heat pump apparatus and a heat exchange apparatus. The heat pump apparatus includes an inlet and an outlet. The heat exchange apparatus includes at least one fluid source conduit configured to replace a section of the existing conduit that is in the flooded state and further configured to permit at least a portion of a fluid that is in the existing conduit to flow therethrough. Further, the heat exchange apparatus includes at least one heat transfer conduit having a fluid inlet and fluid outlet configured to be coupled to the inlet and outlet of the heat pump apparatus to form a closed loop. The at least one heat transfer conduit is further configured to communicate with the fluid source conduit for providing thermal energy exchange between the fluid flowing through the fluid source conduit and a fluid (e.g., water, water and anti-freeze mixture, and refrigerant) flowing in the closed loop.

In one embodiment of the thermal energy exchange system, the existing conduit that is in the flooded state includes a conduit associated with a potable water source. However, other fluid sources, such as wells, lakes, reclaimed water sources, etc., which are in a pressurized state (i.e., a flooded state) may also be used.

In another embodiment of the system, the system further includes connection conduit configured to connect the at least one heat transfer conduit of the heat exchange apparatus to the heat pump apparatus to form the closed loop.

Yet further, the heat exchange apparatus may include, in another embodiment, an enclosure structure configured to enclose at least the fluid source conduit and the heat transfer conduit. Preferably, the enclosure structure includes a lockable access portion.

In yet another embodiment, the thermal energy exchange system may include at least one monitoring device for monitoring at least one parameter associated with the thermal energy exchange system. Further, a parameter

controlled apparatus operable as a function of the at least one monitored parameter may be provided. For example, such monitoring devices may include one or more flow sensors, fluid detection devices, temperature sensors, detection devices, etc. Further, for example, the parameter controlled apparatus may include one or more devices such as a display, an indicator, an alarm, a shut-off valve, a recirculation pump, etc.

In yet still another embodiment of the thermal energy exchange system, the at least one fluid source conduit includes at least a first pipe extending along an axis thereof. The first pipe includes an outer surface at a radial distance from the axis. The first pipe is configured to replace the section of the existing conduit that is in a flooded state. Further, the at least one heat transfer conduit includes a second pipe having a smaller diameter than the first pipe and wrapped about the outer surface of the first pipe (e.g., the second pipe may be helically wound about the first pipe). Further, the second pipe includes an outer surface, and at least a portion of the outer surface of the second pipe may include at least one flattened surface that is in direct contact with a portion of the outer surface of the first pipe (e.g., for providing thermal energy exchange between the first pipe and the second pipe).

In another embodiment of the thermal energy exchange system, the existing conduit, that is in a flooded state, includes a predetermined diameter. In this embodiment, a plurality of fluid source conduits are used. Each fluid source conduit includes a diameter that is less than the predetermined diameter of the existing conduit. Further, each of the plurality of fluid source conduits is associated with a heat transfer conduit that is configured to communicate with the associated fluid source conduit for providing thermal energy exchange between a fluid flowing through the associated fluid source conduit and a fluid flowing in the closed loop. In this embodiment, the heat exchange apparatus may further include one or more couplings to fluidly connect the plurality of fluid source conduits to the existing conduit (e.g., using a manifold coupling).

The heat exchange apparatus described above may be provided separately and apart from the thermal energy exchange system. Further, the associated elements and embodiments directed towards such a heat exchange apparatus may be also separable from the system.

Further, a method for use in installing a thermal energy exchange system, including a heat pump apparatus (e.g., a heat pump apparatus including an inlet and an outlet), is also described herein. The method includes providing a heat exchange apparatus. The heat exchange apparatus includes at least one fluid source conduit configured to replace a section of an existing conduit that is in a flooded state, and further configured to permit at least a portion of a fluid that is in the existing conduit to flow therethrough. The heat exchange apparatus further includes at least one heat transfer conduit having a fluid inlet and a fluid outlet configured to be coupled to the inlet and outlet of the heat pump apparatus to form a closed loop. The at least one heat transfer conduit is further configured to communicate with the fluid source conduit for providing thermal energy exchange between the fluid flowing through the fluid source conduit and a fluid flowing in the closed loop when the thermal energy exchange system is operational. The method further includes evacuating the fluid that is in the section of the existing conduit to be replaced and removing a section of the existing conduit. The at least one fluid source conduit is fluidly coupled to the existing conduit that is in the flooded state.

In various embodiments of the method, the method may further include connecting the at least one heat transfer conduit of the heat exchange apparatus to the heat pump apparatus to form the closed loop; enclosing the heat exchange apparatus in an enclosure structure configured with a lockable access portion; installing at least one monitoring device for monitoring at least one parameter associated with the thermal energy exchange system; manipulating at least one parameter controlled apparatus as a function of at least one monitored parameter; and/or providing a plurality of fluid source conduits and using one or more couplings to fluidly connect the plurality of fluid source conduits to the existing conduit.

Further, another thermal energy exchange system for use with an existing conduit that is in a flooded state is also provided. The existing conduit includes a conduit associated with a potable water source. The thermal energy exchange system includes a heat pump apparatus comprising an inlet and an outlet and a heat exchange apparatus. The heat exchange apparatus includes at least one fluid source conduit configured to replace a section of the existing conduit that is

in a flooded state and further configured to permit at least a portion of a fluid that is in the existing conduit to flow therethrough. The heat exchange apparatus further includes at least one heat transfer conduit having a fluid inlet and a fluid outlet configured to be coupled to the inlet and outlet of the heat pump apparatus to form a closed loop. The at least one heat transfer conduit is further configured to communicate with the fluid source conduit for providing thermal energy exchange between the fluid flowing through the fluid source conduit and a fluid flowing in the closed loop when the thermal energy exchange system is operational. Yet further, the heat exchange apparatus includes an enclosure structure configured to enclose the at least one fluid source conduit and the at least one heat transfer conduit (e.g., the enclosure structure may include a lockable access portion). The thermal energy exchange system further includes at least one connection conduit configured to connect the at least one heat transfer conduit of the heat exchange apparatus to the heat pump apparatus to form the closed loop.

Further, in one or more embodiments, one or more other HVAC apparatus may be used in the thermal energy exchange system as an alternate to the heat pump apparatus.

The above summary of the present invention is not intended to describe each embodiment or every implementation of the present invention. Advantages, together with a more complete understanding of the invention, will become apparent and appreciated by referring to the following detailed description and claims taken in conjunction with the accompanying drawings.

Brief Description of the Drawings

Figure 1 is a general schematic diagram of an exemplary thermal energy exchange system using a heat exchange apparatus that is configured to replace a section of an existing conduit that is in a flooded state in accordance with the present invention.

Figure 2 is a general schematic diagram of an alternate embodiment of a heat exchange apparatus that includes a plurality of heat exchangers according to the present invention that may be used in a thermal energy exchange system as shown generally in Figure 1.

Figure 3 is a schematic diagram of one exemplary embodiment of a thermal energy exchange system, such as that shown generally in Figure 1.

Figure 4 is a perspective view of an exemplary heat exchanger that may be used in the thermal energy exchange system shown generally in Figure 1.

Figure 5A is a cross-section view of the exemplary heat exchanger shown in Figure 4 taken at Line 5A-5A.

Figure 5B is an end view of the exemplary heat exchanger shown in Figure 4 and in the direction shown in Figure 5A.

Figure 6 is a block diagram of one exemplary installation method for a thermal energy exchange system, such as the system shown generally in Figure 1.

Detailed Description of the Embodiments

The present invention shall generally be described with reference to Figure 1. Thereafter, various embodiments shall be described with further reference to Figures 2-6.

Figure 1 shows a general diagram of a thermal energy exchange system 10 according to the present invention. The thermal energy exchange system 10 includes a heat exchange apparatus 12 and a heat pump apparatus 14 (or any other heating/ventilating/air conditioning (HVAC) apparatus also shown generally by reference number 14). The heat pump apparatus 14 is coupled to the heat exchange apparatus 12 by one or more connection conduits 16. The heat pump apparatus 14 is associated with a thermal energy distribution system 21.

In addition, the thermal energy exchange system 10 may employ any (HVAC) apparatus, as opposed to including a geothermal heat pump. For example, the closed loop including a fluid (e.g., refrigerant) therein as described further below, may be provided at least in part by an HVAC apparatus that includes at least one of an air handler that includes water and/or DX coils, a furnace that includes heating and/or DX coils (e.g., gas, oil or electric), any suitable condenser, a cooling tower, and/or an air to air heat pump. In other words, the heat exchange apparatus 12 described herein may be used with a closed loop containing, for example, refrigerant in combination with any HVAC apparatus that can utilize the thermal energy transferred to the refrigerant by the heat exchange apparatus 12.

The present invention uses a heat exchange apparatus including one or more heat exchangers (e.g., heat exchanger 13 as shown in Figure 1) configured to replace a section of an existing conduit 18 that is in a flooded state, as represented by flooded state fluid source 20 in Figure 1. In other words, the heat exchange apparatus 12 operates in a flooded state configuration, as opposed to a gravity state configuration.

As used herein, a conduit being in a flooded state refers to a conduit that is constantly (i.e., at all times) full as a result of a pressurized fluid source (e.g., a forced water source). For example, the fluid source 20 (and, as such, the existing conduit 18 associated therewith) may be part of a city water main,

wherein a pressurized city water supply flows through the heat exchange apparatus 12 (e.g., the heat exchanger 13 replaces a section of a city water main conduit). Further, for example, the fluid source 20 may include a natural spring, well, or river, as long as there is a pressurized flow of fluid provided thereby that completely fills the fluid source conduit 15 of the heat exchange apparatus 12 that replaces a section of existing conduit (e.g., a source that is being pumped or otherwise pressurized). Yet further, for example, other embodiments of the heat exchange apparatus 12 may be used with a lake or pond or other still water source, for example, with the addition of a pump, to provide the pressurization of the fluid source (e.g., a pump to provide a flow of water through the heat exchange apparatus 12 that completely fills the fluid source conduit 15 thereof). One skilled in the art will understand that the existing conduit according to the present invention is in a flooded state except under extraordinary circumstances, e.g., when the section of existing conduit is being replaced with the heat exchanger 12, when a water main is malfunctioning, etc. As such, under normal circumstances, the existing conduit is in a flooded state.

Yet further, the heat exchange apparatus 12 may be adapted to be used with a solar heat source system, wherein the heat exchange apparatus 12 would be configured to replace a conduit section of the solar heat source system in a manner such that, for example, a fluid heated by solar energy would be pumped through the heat exchange apparatus 12 to allow for transfer of heat from the solar-heated fluid.

Further, one skilled in the art will recognize that various fluids from which thermal energy may be exchanged can be used as the fluid of the flooded state fluid source 20. For example, the fluid source 20 may include a fluid such as water, a refrigerant, or any other heat transfer fluid that is provided under pressure through the heat exchange apparatus 12. Further, for example, the flooded state fluid source 20 may be a reclaimed water line. However, such a reclaimed water line would be one that is in a flooded state as opposed to one that is not in a flooded state (e.g., a reclaimed water line that is pressurized and that may, for example, be used for watering purposes, as opposed to a reclaimed water line that is not completely full and/or receives only periodic water flow or a non-constant flow of fluid).

As will be readily understandable to one skilled in the art, the term existing as used herein with the term conduit, does not necessarily refer only to previously existing conduit of a system (e.g., a water main) that has already been installed and is replaced by a heat exchanger. Rather, the term existing also could refer to conduit that would normally be a part of a system (e.g., whether new or old) that is replaced by the heat exchange apparatus 12 according to the present invention, wherein the conduit replaced was never actually installed but rather the heat exchanger was substituted for it during installation. As such, as used herein, the term replaced when referring to a section of existing conduit that is replaced may also mean the substitution of a heat exchanger for conduit that would have otherwise been installed but for the employment of the heat exchanger.

Generally, the heat exchange apparatus 12 includes at least one heat exchanger 13 that includes at least one fluid source conduit 15 configured to replace a section of the existing conduit 18 that is in a flooded state and further configured to permit at least a portion of fluid 20 that is in the existing conduit 18 to flow therethrough. Further, the heat exchange apparatus 12 includes at least one heat transfer conduit 17 having fluid inlet/outlet 24, 26 configured to be coupled to inlet/outlet 30, 32 of heat pump apparatus 14 to form a closed loop, as represented by arrows 36. The at least one heat transfer conduit 17 is configured to communicate with the at least one fluid source conduit 15 for providing thermal energy exchange between the fluid 20 flowing through the fluid source conduit 15 and a fluid flowing in the closed loop 36 when the thermal energy exchange system 10 is operational.

For example, in one embodiment, the heat exchange apparatus includes an inner pipe or conduit through which the fluid 20 (e.g., water of a pressurized water source) will flow. The inner pipe or conduit is wrapped (e.g., helically wound) by another heat transfer pipe or conduit (e.g., coiled about the inner pipe) through which a heat transfer fluid flows (e.g., through which a refrigerant or water flows).

In another embodiment, for example, the heat exchange apparatus 12 includes at least a first pipe extending along an axis thereof. The first pipe includes an outer surface at a radial distance from the axis. The first pipe is

configured to replace the section of the existing conduit 18 that is in a flooded state. Further, the heat exchange apparatus 12 includes a second pipe having a smaller diameter than the first pipe and wrapped about the outer surface of the first pipe. The second pipe also includes an outer surface. At least a portion of the outer surface of the second pipe includes at least one flattened surface that is in direct contact with a portion of the outer surface of the first pipe. As such, the two pipes are in communication with one another and provide thermal energy exchange therebetween.

As used herein, when one conduit is referred to as being wrapped about another conduit, such wrapping may be provided in any number of different configurations. For example, in one configuration, such wrapping is performed such that the conduit is helically wound around the other conduit, such as shown in Figure 4. However, wrapping may also refer to other forms of providing communication between the heat transfer conduit 17 and the fluid source conduit 15, such as coiling the heat transfer conduit 17 longitudinally along the fluid source conduit 15 as opposed to being wound helically about the fluid source conduit 15. Although any number of different wrapping configurations may be used, preferably a helically wound configuration is used. With use of a wrapped configuration, the length of conduit necessary to provide adequate thermal energy exchange can be reduced, for example, relative to other types of closed looped geothermal systems (e.g., buried pipe loops).

The heat exchange apparatus 12 is configured such that the fluid flowing in the closed loop 36 never mixes with the fluid 20 flowing through conduit 18 (e.g., such fluid would have to go through two walls of conduit to mix). Thus, contamination of the flooded state fluid source 20 is prevented, providing for safe operation of the thermal energy exchange system 10.

The heat exchange apparatus 12 is configured such that the flooded state fluid source (e.g., a flooded water supply) can pass therethrough (e.g., through the fluid source conduit 15), providing a substantially even temperature in a constant manner (e.g., uninterrupted) for use in thermal energy transfer. On the other hand, for example, many other heat exchangers conventionally used utilize stagnant or gravity heat sources which may fluctuate in their respective heat intensities. Further, the constant forced flow of fluid (e.g., water through a city

water main) allows for more rapid thermal energy transfer (e.g., heating or cooling) than conventional systems.

With further reference to Figure 1, the fluid source conduit 15 is fluidly coupled to existing conduit 18 by one or more couplings 33, 35. For example, such couplings may include slip form couplings, boot fittings, clamped connections, or any other suitable coupling for providing a fluid tight seal between the fluid source conduit 15 and existing conduit 18.

The heat exchange apparatus 12 is fluidly coupled to the heat pump apparatus 14 by the connection conduit 16, as described above. For example, heat pump apparatus 14 includes inlet/outlet 30, 32 which are coupled to the inlet/outlet 24, 26 by the connection conduit 16 (e.g., supply and return lines). The connection conduit 16 (e.g., supply and return lines) may be any suitable conduit, for example, high density polyethylene (HDPE) pipe may be used for the supply and return lines of the closed loop 36 between the heat exchange apparatus 12 and the heat pump 14 or copper lines may be used in certain configurations with a sacrificial metal positioned proximate thereto (e.g., in a DX heat pump closed loop system).

One or more suitable couplings 19 may be used to provide coupling of the connection conduit 16 to the inlet/outlet 24, 26 of the heat exchange apparatus 12 and the inlet/outlet 30, 32 of the heat pump apparatus. Such couplings may include, for example, iron pipe size (IPS) trans fittings, slip form couplings, boot fittings, clamped connections, or any other coupling suitable for providing a fluid tight seal between the connection conduit 16 and the inlet/outlets of the respective heat pump apparatus 14 and heat exchange apparatus 12.

The geothermal heat pump apparatus 14 may include any suitable apparatus that transfers thermal energy between the heat exchange apparatus 12 and the distribution system 21. For example, the heat pump apparatus 14 may be positioned within a building enclosure defining a space to be heated or cooled. The heat pump apparatus 14 may be of various configurations such that the heat pump apparatus 14 can use the heating or cooling provided by the heat exchange apparatus 12 (e.g., via the cooling air ducts, interior water lines, etc., which form at least a portion of the distribution system 21). For example, the

geothermal heat pump apparatus 14 may be one or more water source heat pumps or one or more DX heat pumps.

With respect to the geothermal heat pump apparatus 14 including a water source geothermal heat pump, for example, the fluid in the closed loop 36 goes through a heat exchanger 23 inside the heat pump apparatus 14 (e.g., located next to a refrigerant compressor, also inside the heat pump apparatus 14). The heat exchanger 23 associated with the heat pump apparatus 14 includes, for example, coil pipes containing refrigerant (e.g., freon) that are wrapped with a coil containing the fluid flowing in the closed loop 36. Preferably, the closed loop 36 contains water or a water and anti-freeze solution (e.g., a solution including a glycol component). As the fluid flows through the closed loop 36 (e.g., with use of a circulation pump) and through the heat exchanger 12, the fluid extracts thermal energy from the fluid flowing through the heat exchanger 12 (e.g., the fluid flowing through the fluid source conduit 15) and transfers it to the heat exchanger 23 in the heat pump apparatus 14. In other words, the fluid flowing in the closed loop 36 is used to modify the temperature of the refrigerant in coils of the heat exchanger 23 of the heat pump apparatus 14. Generally, in such water source heat pump closed systems, the water or water/antifreeze solution remains within the closed loop for the life of the system. As would be ascertainable by one of skilled in the art from the description herein, the flow of the closed loop in a heating mode would be opposite that for a cooling mode.

The geothermal heat pump apparatus 14 may be configured as a water to air, water source geothermal heat pump or a water to water, water source geothermal heat pump. In the water to air, water source geothermal heat pump configuration, the heat pump is associated with a forced air system 21 that distributes hot or cold air through a conventional duct system for both supply and return air. In the water to water, water source geothermal heat pump, the heat pump is associated with a distribution system 21 that distributes heating and cooling through, for example, infloor radiant tubes or air handlers with water coils.

Various configurations of water source heat pumps (e.g., both water to air and also, water to water) that may be used and/or modified for use with the present invention are available from manufacturers such as: Water Furnace

International Inc. of Ft. Wayne, IN (e.g., such as heat pumps sold under the trade designation of Versatec, Premier, or Synergy); Climate Master, Inc. of Oklahoma City, OK; Florida Heat Pump (FHP) Manufacturing, Inc. of Ft. Lauderdale, FL; Mammoth Inc. of Chaska, MN; Carrier Corp. of Farmington, CT; Trane of Tyler, TX; and Maritime Geothermal Ltd. of Petitcodiac, New Brunswick, Canada (e.g., such as heat pumps sold under the trade designation of a Nordic Water to Water, or a Nordic Water to Air heat pump).

With respect to the geothermal heat pump apparatus 14 including a DX geothermal heat pump, for example, the fluid in the closed loop 36, unlike a water source heat pump system, is a refrigerant. Further, instead of the connection conduit being, for example, HDPE pipe, the supply and return lines (e.g., the connection conduit 16) is preferably copper pipe. As the connection conduit 16 is relatively short in accordance with the present invention as compared to most DX heat pump closed loop systems that include buried copper pipe, a much smaller quantity of sacrificial metal is needed to implement the present system (e.g., positioned proximate the copper tube to prevent degradation thereof). Generally, the sacrificial material may be any suitable material, such as a material that includes a metal softer than copper (e.g, zinc).

In operation, for example, in one embodiment, with use of a DX heat pump apparatus, a heating cycle may begin with a refrigerant flowing through the closed loop 36 including the heat transfer conduit 17 of the heat exchange apparatus 12, where the refrigerant absorbs thermal energy (e.g., heat) from fluid 20 flowing through the fluid source conduit 15 and evaporates to form a cooled gas (i.e., the heat exchanger 13 acting as an evaporator). The fluid 20 flowing through the fluid source conduit 15 gives up heat as the refrigerant flows through the closed loop. The gaseous refrigerant from the evaporator passes through conduit (e.g., connection conduit 16) to the heat pump apparatus 14 which includes a compressor. The compressor compresses it, and raises its temperature and pressure.

The hot, compressed gas then flows to an air handler associated, for example, with air distribution system 21 (e.g., when an air distribution system is utilized) which acts as a condenser in the heating mode. Here, air flowing across the condenser absorbs heat from the refrigerant and carries it throughout the

space being heated. As the refrigerant releases its heat, the refrigerant condenses to form a liquid, which then flows through, for example, an expansion device that reduces its pressure and, consequently, lowers its temperature again. Finally, the refrigerant reenters the heat exchanger 13, and the cycle is repeated.

For cooling, the above process is reversed. The compressor sends (e.g., pumps) the hot, dense gas to the heat exchanger 13 (i.e., now acting as the condenser). The fluid 20 flowing through the fluid source conduit 15 absorbs thermal energy (e.g., heat) from the refrigerant in the closed loop. As the refrigerant gives up heat to the fluid 20 flowing in the fluid source conduit 15, the refrigerant cools and condenses into a liquid. The cool liquid refrigerant flows through, for example, an expansion device (e.g., using an orifice or a valve), which further lowers its temperature and pressure. The cold liquid refrigerant then flows through an air handler associated with the air distribution system (e.g., when an air distribution system is used) (i.e., which now acts as the evaporator). For example, air from the space flows across the evaporator tubing, giving up heat to the refrigerant inside the tubes. The cooler air is moved through the space via, for example, duct work. The warmed refrigerant evaporates as it absorbs heat from the air, and then returns to the compressor to repeat the cycle.

Various configurations of DX heat pumps that may be used and/or modified for use with the present invention are available from manufacturers such as: American Geothermal of Murfreesboro, TN; ECR Technologies of Lakeland, FL (e.g., such as heat pumps sold under the trade designation of Earthlinked heat pumps); Hydro Delta of Monroeville, PA (e.g., such as heat pumps sold under the trade designation of Yankee or Twin Line heat pumps); and Maritime Geothermal Ltd. of Petitcodiac, New Brunswick, Canada (e.g., such as heat pumps sold under the trade designation of Nordic Triple Function).

The heat pump apparatus 14 may include various elements depending upon the configuration in which it is being used. For example, the heat pump apparatus may include heat exchangers, reversing valves, metering devices, bypass valves, a compressor, etc. One skilled in the art will recognize that the heat pump apparatus 14 may take one of various forms and the present invention is not limited by any listed or described heat pump apparatus herein or by any

particular system operation description provided herein. Rather, the heat pump apparatus may include any apparatus that transfers the thermal energy provided in the closed loop from the heat exchange apparatus 12, such as, for example, transfer of the thermal energy to a space, an object or structure that is to be heated or cooled (e.g., a transfer of thermal energy using heat exchanger 23 and the distribution system 21).

Generally, the closed loop 36 (i.e., formed with use of at least portions of the heat pump apparatus 14, connection conduit 16, and heat exchange apparatus 12) contains any suitable heat transfer fluid (e.g., suitable depending on the heat pump configuration). With use of a water source heat pump apparatus, the fluid in the closed loop 36 includes, preferably, one of water or a water and anti-freeze mixture. The anti-freeze component preferably includes a glycol component. The glycol component provides both anti-freeze functionality and also enhances heat transfer in the system. With use of a DX heat pump apparatus, a suitable refrigerant is used in the closed loop 36. For example, refrigerants such as R22 and R410A may be used within the closed loop 36. However, although various fluids are listed herein, the present invention is not limited to any particular fluid or to any particular refrigerant listed.

It will be recognized by one skilled in the art that the operation of the system described herein may be modified and/or be performed in many different ways depending upon the configuration of the system, and its varied components. Therefore, the operation described herein is for illustrative purposes only and the present invention is in no manner limited to only the operation as described herein. It will be recognized by one skilled in the art that the heating or cooling provided by the thermal energy exchange system 10 may be used in various applications. For example, defined volume spaces may be heated or cooled, objects may be heated or cooled (e.g., floors, swimming pools, etc.), as well as any other application where heating or cooling is used.

Figure 2 shows a manifolded heat exchange apparatus 70 that may be used in a thermal energy exchange system 10, as shown generally in Figure 1. For example, as shown in Figure 1, heat exchange apparatus 12 includes a single heat exchanger 13. As shown in Figure 2, heat exchange apparatus 70 includes a

plurality of heat exchangers 72, 74, 76 provided in a manifold configuration. Such a configuration may be used with an existing conduit 18 that is in the flooded state and which includes a predetermined diameter that is larger than the diameter of fluid source conduits used in the plurality of manifolded heat exchangers 72, 74, 76.

In other words, each fluid source conduit 73, 75, 77 of each heat exchanger 72, 74, 76 includes a diameter that is less than the predetermined diameter of the existing conduit 18. Each of the plurality of fluid source conduits 73, 75, 77 associated with a particular heat exchanger 72, 74, 76 is associated with a heat transfer conduit 83, 85, 87 that is configured to communicate with the associated fluid source conduit 73, 75, 77 for providing thermal energy exchange between a fluid 20 flowing through the associated fluid source conduit 73, 75, 77 and a fluid flowing in a closed loop (e.g., closed loop 36 as shown in Figure 1) of which the heat transfer conduits 83, 85, 87 are a part thereof.

As shown in Figure 2, each of the three heat exchangers 72, 74, 76 include a fluid source conduit 73, 75, 77, respectively. A 1:3 manifold coupling 78 is provided to fluidly couple existing conduit 18 to the heat exchangers 72, 74, 76 at a first end of the heat exchange apparatus 70. Likewise, a 1:3 manifold coupling element 80 is provided to fluidly couple the existing conduit 18 to the heat exchange apparatus 70 at the other end thereof.

The manifold coupling 78 may be of various configurations, including, for example, a larger diameter connection with three smaller diameter reduction pipes, as well as any other suitable manifold element. Connections with a fluid tight seal between the manifold coupling 78 and the existing conduit 18 may be provided by any number of one or more suitable fittings 82, such as iron pipe size (IPS) trans fittings, slip form couplings, boot fittings, and clamped connections. Connections with a fluid tight seal between the manifold coupling 78 and the fluid source conduits 73, 75, 77, may be provided by any number of one or more suitable fittings 81, such as iron pipe size (IPS) trans fittings, slip form couplings, boot fittings, and clamped connections. One skilled in the art will recognize that such fluid coupling may be the same at the other end of the heat exchange apparatus 70 using manifold coupling 80.

In one configuration, for example, the manifolded heat exchange apparatus 70 may be used with a 12-inch diameter water main 18. With such a large diameter water main, and depending upon the necessary thermal energy transfer required for heat pump apparatus 14, three heat exchangers 72, 74, 76 (each having a four-inch diameter fluid source conduit 73, 75, 77) may be provided in a manifold configuration to replace a section of the 12-inch water main 18. The manifold coupling 78 can be connected to the 12-inch water main using a slip form fitting. Further, the manifold coupling 78 in such a configuration includes three four-inch reduction pipes that may be connected to respective fluid source conduits 73, 75, 77 also by way of slip form couplings. The coupling may be the same at the other end of the heat exchange apparatus 70 using manifold coupling 80.

Further, the heat exchangers 72, 74, 76 each include a heat transfer conduit 83, 85, 87 associated therewith and for use in forming the closed loop (e.g., a closed loop 36 such as described generally with reference to Figure 1). The coupling of such heat transfer conduits 83, 85, 87 into the closed loop may be provided by any number of different configurations. For example, each heat transfer conduit 83, 85, 87 may be coupled into separate closed loops associated with different heat pump apparatus. Further, for example, such heat transfer conduits 83, 85, 87 may be coupled to a single return/supply line as shown in Figure 2. For example, three half-inch diameter heat transfer conduits at the inlet/outlet 90, 92 thereof may be fluidly coupled to a 1½-inch supply/return lines 94, 96 via suitable couplings 98, 99 as illustratively shown in Figure 2.

One skilled in the art will recognize, that depending upon the configuration of the thermal energy exchange system including, for example, the manifolded heat exchange apparatus configuration, the manifold coupling and the fittings used to provide a fluid tight connection between fluid source conduits and the existing conduit 18 will vary. Likewise, depending upon the configuration of the thermal energy exchange system including, for example, the manifolded heat exchange apparatus configuration, the fittings and connections used to provide a fluid tight connection between the heat transfer conduits and the heat pump apparatus 14 will vary.

It will be recognized that the number of manifolded heat exchangers may vary and the present invention is clearly not limited to the manifold configuration as shown in Figure 2. Rather, the number of heat exchangers utilized in the manifolded heat exchange apparatus 70 will vary depending upon various factors such as, for example, those described herein (e.g., heat pump capacity, water flow, etc.).

Further, it will be recognized by those skilled in the art that for each application, the heat exchange apparatus is sized and configured based on various types of information. For example, such heat transfer apparatus configurations may depend on various factors, such as size of the water main, flow rate in the water main, water main temperatures, the size and capacity of the heat pump apparatus 14, the type of connection required by an entity in control of the existing conduit, the type of connections required by such an entity between the heat transfer conduit and the remainder of the closed loop, etc.

Figure 3 shows one schematic diagram of an exemplary thermal energy exchange system 100 that includes a heat pump apparatus 104 (e.g., or multiple heat pump apparatus) located within a dwelling space 105. The heat pump apparatus 104 includes inlet/outlet 132, 134 coupled by connection conduit 112 to inlet/outlet 124, 126 of a heat exchanger 103 that forms a part of a heat exchange apparatus 102 to form a closed loop; the closed loop represented generally by the arrows 136.

The heat exchange apparatus 102, as shown in the exemplary configuration of Figure 3, is attached to a city water main (e.g., a pressurized water source) as represented by existing conduit 138 and water flow 120. The heat exchange apparatus 102 is located under the street with the buried city water main 138. This is represented generally by the showing of curb and gutter 108.

In other words, heat exchange apparatus 102 includes at least one heat exchanger 103 (or multiple heat exchangers, if in a manifolded configuration). The heat exchanger 103 includes fluid source conduit 111 that replaces a section of (e.g., that is inserted into) the city water main 138. For example, a section of the city water main 138 is cut out and replaced by the heat exchanger 103,

thereby allowing the city water supply 120 to flow through the fluid source conduit 111 of the heat exchanger 103. The fluid source conduit 111 is fluidly coupled to the water main 138 using couplings, such as coupling 141 to provide a fluid tight seal therebetween.

The heat exchanger 103 further includes a heat transfer conduit 113 wrapped about the outer surface of the fluid source conduit 111, as shall be described, for example, with reference to Figures 4 and 5 herein. The heat transfer conduit 113 includes the inlet/outlet 124, 126 which are coupled to the inlet/outlet 132, 134 of heat pump apparatus 104 to form the closed loop 136, as described herein, using connection conduit 112.

The heat pump apparatus 104 (e.g., which may include a heat exchanger 107 if a water source heat pump is used) and an associated distribution system 106, are substantially the same as that described with reference to Figure 1 and shall not be described in further detail with reference to Figure 3. Likewise, connection conduit 112 is substantially the same as described above with reference to Figure 1.

The heat exchange apparatus 102, as shown in Figure 3, is encased in an enclosure structure 160 configured, at least in one embodiment, to enclose at least the fluid source conduit 111 and the heat transfer conduit 113. Further, the enclosure structure 160, may also enclose any coupling apparatus used to couple the fluid source conduit 111 to the existing conduit 138 and/or any coupling apparatus used to couple the heat transfer conduit 113 to the connection conduit 112.

The enclosure structure 160 includes an access portion 161 that allows restricted access into the interior of the enclosure structure 160, for example, to service the heat exchange apparatus 102. The access portion 161 to the enclosure structure 160 may be configured in various manners. Preferably, the access portion 161 is a lockable access. In one embodiment, a manhole access lid would be used as part of the enclosure structure 160. Such access products are conventionally available.

The enclosure structure 160 preferably is sized such that it encloses the heat exchanger 103 in addition to couplings 141, 142, 145 used to fluidly couple the at least one fluid source conduit 111 to the existing conduit 138. Various

configurations of the enclosure structure 160 may be used according to the present invention. For example, a concrete enclosure may be used. Such a concrete enclosure may be pre-cast and positioned in place. Alternately, such a concrete enclosure may be poured in place using forms defining the enclosure (e.g., styrofoam forms). Further, for example, the enclosure may be constructed of other materials, such as, for example, steel or aluminum. In such a case, at least a portion of the enclosure is preferably constructed and placed in position (e.g., four side walls of the structure may be prefabbed and positioned, with the cover being positioned later).

In one embodiment, the enclosure structure 160 is a five-sided rectangular structure that includes four side walls and a top. Two of the opposing side walls have openings configured for receiving the existing conduit 138 that is in the flooded state. The enclosure structure 160 is placed over such existing conduit 138. Further, various openings for providing the return and supply lines to and from the heat exchange apparatus 102 are also defined in the enclosure structure. One will recognize that various modifications to the enclosure structure may be made without negating the purpose of preventing unauthorized access to the heat exchange apparatus 102.

As shown in Figure 3, the thermal energy exchange system 100 may include various other components. For example, a heat exchange apparatus wall failure alarm 139 may be used to detect leaks that may be present within the enclosed structure 160. For example, the failure alarm 139 may include a moisture sensor wired to an indicator, such as, for example, an audible, visual, or the like indicator (e.g., a remote flashing red light). In the event of a leak in the fluid source conduit 111, a leak in the connection between the water main 138 and the fluid source conduit 111, a leak in the heat transfer conduit 113, or a leak in the connection between the heat transfer conduit 113 and the connection conduit 112, the sensor would detect moisture and set off the indicator. Many components that may be employed to carry out such functions are available, such as low voltage sensors or other components.

As the moisture sensor is to detect moisture within the enclosure 160, the sensor would be positioned therein in a position suitable for detecting such moisture, preferably on a lower side wall thereof above the bottom surface (e.g.,

gravel bottom). The indicator would be provided at any suitable site for alerting appropriate personnel (e.g., in the building or at street level).

Further, a contaminate detection device with an associated alarm represented generally by sensor 154 may be used to detect contamination within the closed loop 136. For example, contamination from compressor oil in the closed loop may be detected. If such a leak is detected, an alarm associated therewith, and/or a shut-off valve, may be activated to shutdown the system.

A flow meter 152 may also be provided on the closed loop 136 to monitor the flow within the closed loop 136 and provide appropriate information as necessary (e.g., information to control the heat pump, to personnel overseeing operation of the system, etc.). The flow meter 152 may, for example, be attached to the inlet/outlet 134 of the closed loop 136 at a location within the building and relatively close to the heat pump apparatus 104, whereby the flow of the fluid within the closed loop 136 can be monitored. The fluid within the closed loop 136 is moved within the closed loop by one or more components within the heat pump apparatus 104, and such further flow may be controlled thereby. The fluid in the closed loop 136 preferably fills the entire closed loop and is under pressure, e.g., such as with use of a circulation pump, to provide for flow therethrough.

Likewise, a flow meter 177 may be positioned on the fluid source conduit 111 of the heat exchanger 103 to monitor the water main flow. Information concerning such water main flow may be used as necessary by associated personnel, or in the control of one or more other components of the system.

A water main recirculation pump 179 may also be used in the thermal energy exchange system 100. For example, the water main recirculation pump 179 may be controlled by an indication of low water flow as measured by flow meter 177. The water main recirculation pump is preferably positioned between the heat exchanger 103 and the existing conduit 138 (at either end of the heat exchange apparatus 102) with use of a suitable coupling device 145 (e.g., slip form coupling, boot fitting, and clamped connection) between the fluid source conduit 111 and a first inlet/outlet of the pump 179, as well as coupling device 142 (e.g., slip form coupling, boot fitting, and clamped connection) between a

second inlet/outlet of the pump 179 and the existing conduit 138. The water main recirculation pump 179 is preferably a water-lubricated water pump.

Yet further, various temperature gauges may also be used in the thermal energy exchange system 100 to provide information about water temperatures at various positions in the system 100. For example, one water temperature gauge 183 may be used on the fluid source conduit 111 to monitor water main temperatures. In addition, temperature gauges 189 and 193 may be associated with the closed loop 136 (e.g., a temperature gauge on the supply conduit and one on the return conduit between the heat pump apparatus 104 and the heat exchange apparatus 102). Such water temperature gauges 189, 193 would provide information with respect to the amount of thermal energy transfer from the fluid 120 flowing through the fluid source conduit 111 to the fluid flowing in the closed loop 136.

It will be readily apparent to one skilled in the art that various other components, such as monitoring devices or parameter controlled apparatus such as that operable as a function of a monitored parameter of the thermal energy exchange system 100, may be used according to the present invention. One skilled in the art will recognize that those listed herein is in no manner a complete listing of all such components that may be used in the system. For example, other apparatus, including displays for monitoring the system, alarms, shut-off switches, detection devices, etc., may be used according to the present invention.

The operation of the thermal energy exchange system 100 is substantially equivalent to that described with reference to Figure 1 and shall not be described again with reference to Figure 3. However, in general, the present invention allows for the flow of a fluid (e.g., water when a water source heat pump is used, or a refrigerant if a DX heat pump is used) from the geothermal heat pump apparatus 104 through the closed loop 136 to the heat exchange apparatus 102, whereby the heat exchange apparatus 102 transfers heat from the city water supply 120 (or, in the summer months, cooling from the water supply 120) to the fluid flowing in the closed loop 136. The fluid flowing in the closed loop 136 returns to the geothermal heat pump apparatus 104 which transfers that heat, or

cooling, to provide a variety of building space conditioning functions with use of, for example, the distribution system 106, such as described herein.

The present invention is more efficient and economical than conventional apparatus in that it requires less conduit and uses an easily and readily available heating and cooling source (that being, for example, the city water main supply) in the embodiment shown in Figure 3. Further, the present invention allows for the more rapid and even transfer of thermal energy from the fluid source, such as the city water supply 120 which is in a flooded state such that fluid flow is constantly provided through the heat exchange apparatus 102. Further, the flooded state also reduces the need for cleaning, as the water may flow rapidly and freely through the heat exchange apparatus 102 at times, which may prevent build-up of residue along the inside of the fluid source conduit 111 of the heat exchanger 103.

The conduit connections of the thermal energy exchange system 100 may be provided as relatively simple and straight connections, which, in most part, eliminates many curves and bends that may weaken the conduit. In one embodiment, the system is installed below grade level. However, other installations, such as above ground level, are also contemplated. For example, by inserting an elbow down joint in both inlet and outlet portions 132, 134 of the closed loop 136 near the heat pump apparatus 104 and within the building 105, the closed loop 136 may exit the building below grade.

Figure 4 shows a perspective view of an exemplary heat exchanger 200 that may be used in the heat exchange apparatus described herein with reference to Figures 1-3. The heat exchanger 200 includes a fluid source conduit 202 and a heat transfer conduit 204 in communication with the fluid source conduit 202 for providing thermal energy exchange between fluids carried within the respective conduits. The fluid source conduit 202 includes a heat conductive pipe (e.g., a copper tube) extending along axis 201 (i.e., extending longitudinally). The heat conductive pipe can vary in diameter depending, for example, on the size of the existing conduit with which the heat exchanger 200 is to be used (e.g., the size of the water main or other water supply, the use of manifolding, etc.). The heat conductive pipe 202 includes an outer surface 210 at a radial distance from the axis 201.

The heat transfer conduit 204 includes a heat conductive pipe (e.g., a copper tube) that is wrapped about the outer surface 210 of the fluid source conduit 202 (e.g., the number of wraps may vary depending on the application). The heat transfer conduit (e.g., copper tube 204) includes an outer surface 230. At least a portion of the outer surface 230 of the heat transfer conduit 204 is flattened, as shown by reference numeral 212 in Figure 5A. The at least one flattened surface 212 is provided such that it is in direct contact with a portion of the outer surface 210 of the fluid source conduit 202 for providing effective thermal energy exchange between the fluid source conduit 202 and the heat transfer conduit 204 (e.g., the inner copper tube and the outer copper tube wrapped thereabout).

As further shown in Figure 5A, other portions of the heat transfer conduit 204 are also flattened, as represented by reference numeral 215. In such a manner, each wrap of the heat transfer conduit 204 can be positioned very close to the adjacent wraps with very little air gap between the wrapped conduit (e.g., outer copper pipe) and the outer surface 210 of the fluid source conduit 202. Such additional flattened surfaces 215 allow for a larger quantity of wraps within the same length of fluid source conduit 202 as compared to a configuration that would not have such flattened surfaces.

The diameter of the heat transfer conduit 204 wrapped around the outside of the fluid source conduit 202 can vary depending on the water volume needed in the closed loop for the heat pump apparatus to which it is connected. In one particular embodiment, the outer copper tube is machined onto the larger inner copper tube to achieve a tight fitting. This eliminates the need to solder the outer tube (e.g., the heat transfer conduit 204) to the inner tube (e.g., the fluid source conduit 202). Use of large amounts of solder adversely affects the efficiency of the heat exchange between the fluid source conduit 202 and the heat transfer conduit 204. As shown in Figures 4 and 5B, only a small solder connection 220 is used to tack the heat transfer conduit 204 to the fluid source conduit 202 (e.g., the inner copper pipe) at each end 206, 208 of the heat exchanger 200 as the heat transfer conduit 204 extends or otherwise leaves the outer surface 210 of the fluid source conduit 202.

In one embodiment, the inner fluid source conduit 202 is sized to accommodate the size of the water main to which it is connected. Likewise, the outer tube (i.e., the heat transfer conduit 204) will be sized to accommodate the volume of water needed for the heat pump apparatus to which the heat exchanger 200 is connected. In other words, depending upon the capacity of the heat pump apparatus to which the heat exchanger 200 is connected, the size of the heat exchanger 200 will vary, for example, the length along axis 201 may vary, as well as the diameter of the conduits and the number of heat exchangers.

Preferably, according to the present invention, copper tubing is used to construct the heat exchanger 200. However, other conductive materials capable and effective in the transfer of thermal energy may also be suitable. For example, materials such as stainless steel and the like may also be used for providing heat exchanger 200.

As described herein, heat exchanger 200 may also be wrapped in alternative configurations. For example, instead of helically winding the heat transfer conduit 204 about the outer surface 210 of the fluid source conduit 202, wraps of the heat transfer conduit 204 may be provided in a longitudinal manner parallel to the axis 201, or in any other alternate wrapped manner.

Figure 6 shows one exemplary embodiment of an installation method 300 for installing one or more portions of a thermal energy exchange system, such as that shown in Figures 1-5. Reference numerals of system components, such as those shown in Figure 1, will be used to describe the installation method 300.

Generally, the method 300 includes evacuating fluid that is in the section of existing conduit 18 that is to be replaced (block 302). The section of existing conduit 18 is removed, as shown in block 304. A heat exchanger including a fluid source conduit and at least one heat transfer conduit, such as that shown in Figure 4, is fluidly coupled to the existing conduit 18 that is in the flooded state (block 306). For example, fluid source conduit is coupled to existing conduit 18 at both ends of the heat exchange apparatus. Thereafter, a flow of fluid is provided through the fluid source conduit (block 308). Connection of heat transfer conduit to the heat pump apparatus 14, as well as installation of other associated apparatus, is thereafter performed (block 310).

In slightly more detail, the installation method 300, at least in one exemplary embodiment, can be performed in the following manner. For example, a water main trench may be evacuated at a predetermined length and width to expose a water main. Another trench is excavated from the water main trench to a building for placement of supply and return lines between a heat pump apparatus in a building and the heat exchanger apparatus that is replacing a section of the water main. One or more portions of an enclosure structure is then provided in the first trench. For example, a prefabricated enclosure structure may be placed within the water main trench or, for example, the side walls of a concrete enclosure structure may be formed and poured. The enclosure may be positioned at various times during the installation process.

The water main may be turned off at the closest two points to where the heat exchanger is to replace the removed section of water line. In other words, the fluid in the section of existing conduit to be replaced is evacuated. As an alternate to turning off the water, a bypass saddle tap could be used.

A section of the water main is cut and removed for insertion of the heat exchanger. The fluid source conduit or conduits of the heat exchange apparatus are connected to the city water main (e.g., the existing conduit) with a connection such as, for example, a slip form connection. Such connections are made at each end of the heat exchanger. If a recirculation pump is required or desired, it is installed between the connection used to couple the heat exchanger to the existing conduit and the heat exchanger itself. The fluid source conduit is then tested by turning the water main on and checking for any leaks in the connections.

The pipes for the supply and return lines (e.g., connection conduit) are placed in the trench between the heat pump apparatus and the heat exchanger to connect the heat transfer conduit of the heat exchanger with the heat pump apparatus to form the closed loop. Such connections may be accomplished with transition fittings (e.g., an IPS trans fitting). Again, such connections may be tested, for example, using an air test of the heat transfer conduit and the supply and return lines.

Thereafter, various associated elements may be installed. For example, flow meters may be installed by attaching one of the flow meters to the fluid

source conduit and another to the heat transfer conduit or other portion of the closed loop. Further, temperature gauges may be attached to the heat transfer conduit at both the supply side and return side of the closed loop. A moisture sensor may be installed in the enclosure structure, and an alarm or indicator associated with the moisture sensor may be installed in a suitable location (e.g., a remote location readily visible from the street). The moisture sensor is then connected to the indicator.

With the enclosure structure in place, a fill material (e.g., gravel) may be placed in the bottom of the enclosure structure. The top of the enclosure structure may be poured or placed thereon with an opening for a manhole access or some other lockable access portion. The trenches are back-filled and compacted. If the water main was located in a street, the street opening would be replaced with concrete or asphalt and reinforced, as necessary.

With the heat exchange apparatus in position, along with portions of the connection conduit, the supply and return lines to the heat exchanger can be extended to inside the building for connection to the heat pump apparatus positioned therein. At least in one embodiment, the connection conduit for forming the closed loop is connected to circulation pumps associated with the heat pump, and the circulation pumps are connected as required by the heat pump apparatus. Further, the heat pump is coupled to an associated heating and cooling distribution system (e.g., duct work or radiant tubes, etc.), and all further electrical and/or temperature sensing devices (e.g., thermostats) are connected to the geothermal heat pump apparatus for operation thereof.

The preceding described embodiments are illustrative of the practice of the invention. It is to be understood, therefore, that other expedients known to those skilled in the art or disclosed herein may be employed without departing from the invention or the scope of the appended claims. For example, various apparatus or steps of one embodiment described herein may be used with one or more other embodiments described herein to form various combinations of methods, systems, or apparatus contemplated by the present invention. Further, for example, various heat pump apparatus configurations (as well as various distribution systems) may be used with the heat exchanger configurations described herein. In addition, the end object or space affected by the transfer of

thermal energy according to the present invention may be varied, and is not limited to only heating or cooling of a particular defined volume. As such, the present invention includes within its scope other methods, systems and apparatus for implementing and using the invention described herein.